

# Advancements in structural break testing

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## Summary

Structural break analysis is used in Chapter 3 to trace evidence of shift-contagion in financial time series data. A sequential testing procedure is described, which uses the established maximum likelihood ratio test to detect multiple structural breaks in a multivariate data system. In a linear regression model of financial returns, shift-contagion is expected to involve a significant increase in the contemporaneous correlation between the residuals of the series. Since contagion is associated with times of crisis, volatility changes and changes in other parameters of the model can also be found by the proposed testing procedure. Applied to yield spreads of euro area governments, a large number of structural breaks are found during the period of the European sovereign debt crisis. The estimated break dates for correlation changes are diverse. Notably, volatilities change at different times than correlations, as contagion is not bound to happen at the beginning of crisis periods. The empirical study is augmented by the calculation of spillover index values to measure spillover-contagion. The level of spillover is particularly high during 2011 and 2012, and periphery countries transmit an large part of their shocks to the rest of Europe. Overall, the findings demonstrate a substantial degree of heterogeneity between euro area countries. Yet, the dynamics of European shock transmissions are shown to be rich, and both shift-contagion and spillover-contagion have occurred during the sampled period of time.

The usage of maximum likelihood ratio testing to detect multiple structural breaks in large, multivariate data sets has proven to be time consuming. This is particularly true, if various possible constellations of common structural break hypotheses are tested, and if simulation-based bootstrap methods are used to either determine critical test values empirically or to find confidence intervals for structural break date estimates. The execution time of the applied dynamic program increases quadratically with the number of observation dates. Chapter 4 presents a rolling window algorithm that can be used as a break detection heuristic. The algorithm calculates single break likelihood

ratio values in rolling data windows, which reduces the execution time substantially. A Monte Carlo simulation study shows that the rolling window algorithm has similar testing power as the dynamic program in large data samples. In simulations where parameters shift in the same direction several consecutive time, the rolling window algorithm is even shown to locate the breaks more efficiently than the dynamic program. When applied to find error volatility changes in a regression model of European central government bond yield differences between 2003 and 2016, six structural breaks are detected for each series. The chapter offers interpretation for the detected changes as they relate to the Global Financial Crisis, the European sovereign debt crisis and policy measures by the European Central Bank.

In structural break testing, when a maximum likelihood ratio statistic is used to find change, this change is captured by model parameters. That is, the structural break is inferred, if the data fit of a model is significantly improved by allowing two different sets of parameter values (before and after the structural break date). Finding a structural break means that allowing abrupt change at the break date enables a better representation of the sampled observations than not allowing change at all, but the finding does not prove that the change is actually abrupt. When interpreting empirical structural break results, such as the euro area contagion findings of Chapter 3 and the European yield volatility changes of Chapter 4, it is important to recognize this uncertainty about the type of transition. Chapter 5 further investigates the volatility changes of Chapter 4 by applying a novel abruptness test of parameter change. The abruptness test consists of the summation of likelihood ratios that lie within a specified range of the maximum likelihood ratio. In accordance with the specification under structural break model, the test assumes that the parameter change is abrupt under its null hypothesis. If the sum of likelihood ratios is larger than typically observed, the abruptness hypothesis is rejected in favor of a hypothesis with more gradual change. A Monte Carlo study underlines the validity of this test design for data that originates from smooth transition models. In the empirical application of European yields, many volatility transitions are found to be non-abrupt, especially during the European sovereign debt crisis episodes. The changes observed in periphery countries appear to accumulate gradually over time.

So far, all chapters have used the maximum likelihood ratio statistic, which is designed to find the a structural break that optimizes the model fit to the given observations. Chapter 6 advances structural break testing by introducing a cross-validated error estimation test. Here, structural breaks are found that optimize the estimated model fit to unobserved data. The test is concerned with the out-of-sample validity of the inferred model, a concept that is standard practice in statistical learning and feature selection. In a Monte Carlo study, the performance of the proposed test is systematically compared to the performance of the maximum likelihood ratio test. Either method frequently detects break dates closer to the true location in the simulated data than the other method. The new test, however, does so more frequently than the maximum likelihood ratio. For the test, prediction errors are estimated by cross-validated mean squared errors, repeatedly, to reveal the estimation uncertainty. The collection of estimated break dates can serve as the foundation of a rich structural break analysis, as shown in the empirical application of the chapter. Here, it is studied whether the association between lagged U.S. government bond yields and European government bond yields has changed between 2014 and 2016. Following the adoption of a bond purchase program by the European Central

Bank that is similar to the U.S. quantitative easing program, the association has become significantly larger after April 2015 for six euro area core countries as well as Denmark.

